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# MULTIVARIATE STATISTICAL ANALYSIS OF GODAVARI RIVER WATER QUALITY FOR IRRIGATION PURPOSES AT RAJAHMUNDRY AND DHAWALESWARAM, AP

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***ABSTRACT***

***The present work involves the modelling of water quality of River Godavari, for irrigation purposes at Rajahmundry and Dhawaleswaram, in Andhra Pradesh using the multivariate statistical techniques such as Factor Analysis (FA), Cluster analysis (CA), and Principal Component Analysis (PCA). The water quality assessment is done, with the help of two Water Quality Indices (WQI) i.e., National Sanitation Foundation Water Quality Index (NSFWQI) and Weighted Arithmetic Index Water Quality Index (WAIWQI). The data is obtained from the department of Irrigation and Command Area Development (ICAD) and Hydrology Project Circle, Andhra Pradesh, for the period of 2004-2012, which comprises of 9 irrigation parameters. The study using the Water Quality Indices (WQI) indicated that, the quality of water is found to be fair. The Multivariate Analysis has shown the highest pollution, loadings for the monsoon season. The variation in EC_FLD, TDS is found to vary with the degree of pollution. The study indicated that, the quality of River Godavari at Rajahmundry and Dhawaleswaram is moderate at present, for irrigation purposes and its quality in the future might not have a perceptible change, if the present conditions prevail and can be used for irrigation purposes.***

***KEYWORDS: River Godavari, Multivariate Analysis, National Sanitation Foundation Water Quality Index (NSFWQI), Weighted Arithmetic Index Water Quality Index Method (WAIWQI) & EC_FLD & TDS***

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**Original Article**

## INTRODUCTION

Water Management is important, since it helps in determining future irrigation expectations under the set policies and regulations. Water, once an abundant natural resource, is becoming a more valuable commodity due to droughts and over usages. Ideally, water resource management has regard to all the competing demands for water and seeks to allocate water on an equitable basis, to satisfy all uses and demands. Most of the water for irrigation purposes is drawn from surface water sources, as they are the large fresh water sources like major rivers. However, the major rivers in India like Ganga, Yamuna, Brahmaputra, Mahanadi, Godavari, Krishna and the Kaveri are prone to rapid contamination at present. This is due to the presence of the number of cities, pilgrim places and industries on the banks of the rivers. Despite of many schemes of river water quality monitoring and assessment, the rivers are getting contaminated and the river Godavari is not an exception. And there was a major concern to study the water quality of River Godavari because; the river has been experiencing an alarming rate of pollution

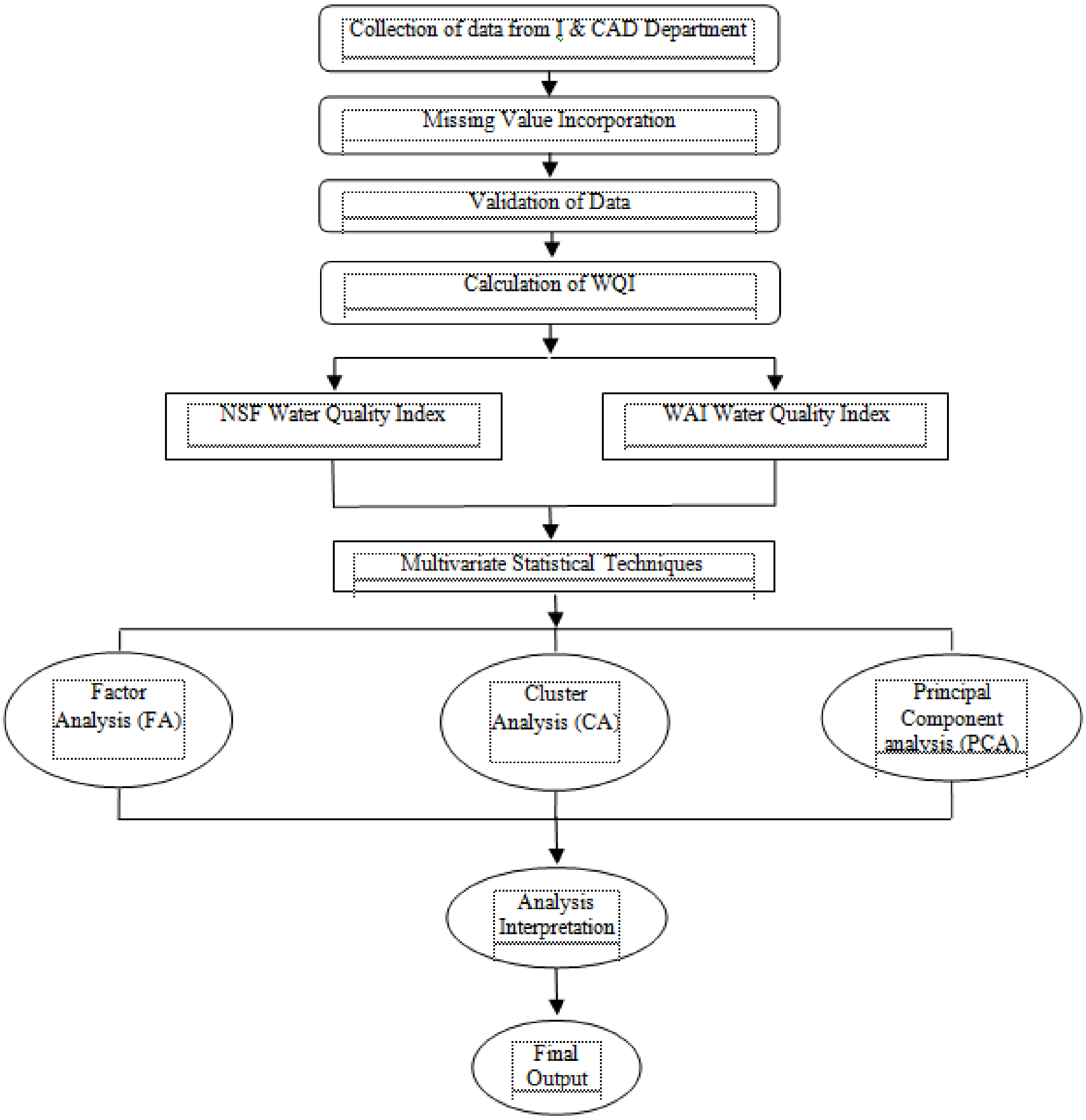
due to several factors.

Yong Cao[7] et.al (1999), have developed a new standardization model, which incorporates water quality standards into data standardization, that provides a mechanism to improve the biological relevance of multivariate analysis making the assessment of water quality more ecologically meaningful. Multivariate statistical analysis, offers an objective method to estimate the observed strengths of the given processes that involves simultaneous changes of several water-quality parameters (Petersen[4] et.al 2001). Multivariate statistical techniques were applied for the evaluation of spatial variations and the interpretation of a large complex water quality data set of rivers. The factors indicate that, the possible variances in water quality may be due to either sources of anthropogenic origin, or due to different biochemical processes that are taking place in the system. These analytical techniques for the processing of water quality parameters are power full tools, for the classification as well as identification of possible sources of pollution. The techniques are also helpful in providing the possible mechanism with justification, by simple reasoning, to the causes of variation in water quality parameters. (Abbas F. M. Alkarkhi[1] et.al 2008). The deterioration of water quality in the rivers, due to anthropogenic activities like industrial effluents, automobile emissions and phosphatic fertilizers in urban environments, can be evaluated by the studies of WQI. (Pradyusa Samantray[5] et.al 2009, M. Vasanthavigar[6] et.al 2010). A precise technique of principle component analysis (PCA) acts as an advance tool, for surface water modeling and forecasting and is used to simplify and understand the complex relationship among water quality parameters. This assessment presents the importance and advantages, posed by multivariate statistical analysis of large and complex databases, in order to get improved information about the water quality and then helps to reduce the sampling time and cost for reagent used, prior to analyses. (Mohd Fahmi Mohd Nasir[3] et.al 2011). The usefulness of using multivariate statistical techniques, in assessing water quality is in determining the amount of pollutants, pollution sources and making relevant data available concerning the water quality, designing water quality monitoring network, understanding temporal variations and overall water quality management. (Zare[9] et.al 2011, Ebrahim Fataei[2] et.al 2012).

**Study Area**

This study is bonded with the water quality of River Godavari. Godavari is a major waterway in central India, originating in the Western Ghats at Trimbakeshwar, in the Nasik District of Maharashtra and flowing eastward by 1465 km across Deccan plateau, through the state of Maharashtra. It enters Telangana at Basar in Adilabad District. Rajahmundry is the second largest city on the banks of River Godavari, in Andhra Pradesh. At Rajahmundry, the river Godavari is in its widest form, having a width of approximately 5 km from Rajahmundry to the other bank at Kovvur. The study was conducted at the areas Rajahmundry and Dhawaleswaram, located on the banks of River Godavari. Rajahmundry is located at 16.98˚N and 81.78˚E, with an average elevation of 14 meters MSL (45 feet). Dhawaleswaram is a suburb situated near Rajahmundry, in the East Godavari district of Andhra Pradesh. It is approximately four kilometers away from Rajahmundry. Dhawaleswaram is located at 16.57˚N and 81.48˚E. Sir Arthur Cotton built a barrage across river Godavari at Dhawaleswaram. The barrage provides water for agriculture purpose, for both the East and West Godavari districts.

## METHODOLOGY




## RESULTS AND DISCUSSIONS

The seasonal WQI values are evaluated using NSFWQI and WAIWQI methods considering 9 irrigation parameters at both Rajahmundry and Dhawaleswaram stations.

**Table 1: Average Seasonal Variations of NSFWQI & WAIWQI**

| WQI | NSFWQI | | WAIWQI | |
|---|---|---|---|---|
| **Study Area** | **Rajahmundry** | **Dhawaleswaram** | **Rajahmundry** | **Dhawaleswaram** |
| Pre-Monsoon | 34.13 | 34.94 | 39.70 | 44.26 |
| Monsoon | 25.54 | 24.13 | 34.81 | 27.52 |
| Post-Monsoon | 28.24 | 32.36 | 37.83 | 47.45 |

The following tables depict the results of Descriptive statistics, Total Variance, Scree Plot and Factor Matrix from the FA and PCA, w.r.t Irrigation parameters at both Rajahmundry and Dhawaleswaram respectively.

**Table 2: Descriptive Statistics (FA and PCA at Rajahmundry and Dhawaleswaram)**

| Study Area | Rajahmundry | | | Dhawaleswaram | | |
|---|---|---|---|---|---|---|
| **Parameters** | **Mean** | **Std. Deviation** | **Analysis (N)** | **Mean** | **Std. Deviation** | **Analysis (N)** |
| EC_FLD | **189.14** | **31.91** | 12 | **192.75** | **31.33** | 12 |
| pH_FLD | 7.92 | 0.17 | 12 | 7.91 | 0.20 | 12 |
| TDS (mg/L) | 93.39 | 13.28 | 12 | 100.48 | 17.87 | 12 |
| Cl (mg/L) | 23.97 | 6.90 | 12 | 41.66 | 7.07 | 12 |
| HAR_Ca(mg/l) | 41.21 | 5.18 | 12 | 72.25 | 10.73 | 12 |
| HAR_Tot (mg /l) | 75.32 | 19.67 | 12 | 21.23 | 8.25 | 12 |
| Na% (%) | 25.28 | 3.03 | 12 | 23.85 | 3.59 | 12 |
| RSC | 0.10 | 0.04 | 12 | 0.10 | 0.05 | 12 |
| SAR | 0.54 | 0.22 | 12 | 0.64 | 0.30 | 12 |

From the above cited table 2, it is observed that, the highest mean and standard deviation values are obtained for the parameter EC_FLD, which has the greater influences on the quality of water.

Tables 3 & 4 gives the correlation matrix in a rectangular array of numbers, which gives the correlation coefficients between a single variable and every other variables in the analysis.

**Table 3: Coorelation Matrix (FA and PCA at Rajahmundry)**

| Parameters | EC_FLD | pH_FLD | TDS (mg/L) | Cl (mg/L) | HAR_Ca (mg/l) | HAR_Tot (mg /l) | Na% (%) | RSC | SAR |
|---|---|---|---|---|---|---|---|---|---|
| EC_FLD | 1.000 | | | | | | | | |
| pH_FLD | 0135 | 1.000 | | | | | | | |
| TDS (mg/L) | 0.957 | 0.104 | 1.000 | | | | | | |
| Cl (mg/L) | 0.620 | 0.067 | 0.727 | 1.000 | | | | | |
| HAR_Ca(mg/l) | 0.424 | 0.184 | 0.383 | 0.305 | 1.000 | | | | |
| HAR_Tot (mg /l) | 0.798 | -0.135 | 0.734 | 0.519 | 0.064 | 1.000 | | | |
| Na% (%) | 0.057 | -0.597 | 0.180 | 0.189 | -0.441 | 0.114 | 1.000 | | |
| RSC | 0.169 | -0.067 | 0.130 | -0.121 | -0.247 | 0.027 | 0.582 | 1.000 | |
| SAR | 0.304 | -0.309 | 0.394 | 0.280 | -0.384 | 0.249 | 0.821 | 0.640 | 1.000 |

**Table 4: Coorelation Matrix (FA and PCA at Dhawaleswaram)**

| Parameters | EC_FLD | pH_FLD | TDS (mg/L) | Cl (mg/L) | HAR_Ca (mg/l) | HAR_Tot (mg /l) | Na% (%) | RSC | SAR |
|---|---|---|---|---|---|---|---|---|---|
| EC_FLD | 1.000 | | | | | | | | |
| pH_FLD | 0.541 | 1.000 | | | | | | | |
| TDS (mg/L) | 0.896 | 0.526 | 1.000 | | | | | | |
| Cl (mg/L) | 0.695 | 0.336 | 0.826 | 1.000 | | | | | |
| HAR_Ca(mg/l) | 0.947 | 0.601 | 0.877 | 0.703 | 1.000 | | | | |
| HAR_Tot (mg /l) | 0.875 | 0.514 | 0.749 | 0.562 | 0.893 | 1.000 | | | |
| Na% (%) | 0.588 | 0.330 | 0.475 | 0.305 | 0.389 | 0.523 | 1.000 | | |
| RSC | 0.341 | 0.280 | 0.437 | 0.431 | 0.191 | 0.013 | 0.508 | 1.000 | |
| SAR | 0.425 | 0.057 | 0.311 | 0.246 | 0.186 | 0.380 | 0.930 | 0.465 | 1.000 |

The table 5 cited below, shows the percent of variance attributable to each factor and the cumulative variance of the factor and the previous factors. The below mentioned table gives the highest percentage variance, obtained among the extracted values.

**Table 5: Total Variance (Factor Analysis at Dhawaleswaram)**

| Factor | Initial Eigen Values | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % Variance | Cumulative % | Total | % Variance | Cumulative % | Total | % Variance | Cumulative % |
| 1 | 5.27 | 58.62 | 58.62 | 5.15 | 57.26 | 57.26 | 4.29 | 47.76 | 47.76 |
| 2 | 1.66 | 18.52 | 77.15 | 1.58 | 17.57 | 74.83 | 2.10 | 23.40 | 71.16 |
| 3 | 0.94 | 10.47 | 87.62 | 0.78 | 8.72 | 83.55 | 1.11 | 12.38 | 83.55 |

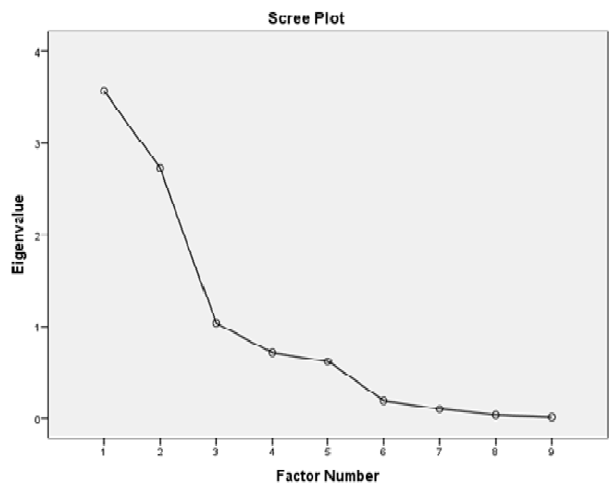



**Figure 1: Scree Plot (FA at Rajahmundry)**

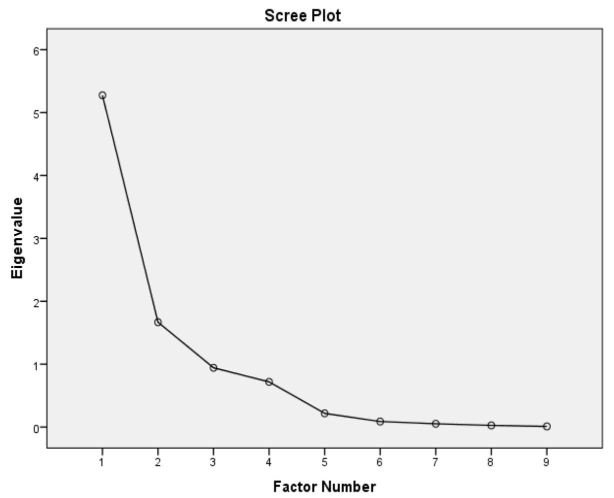



**Figure 2: Scree Plot (FA at Dhawaleswaram)**

The Scree Plot is a graph of the Eigen values, against all the factors. The graph is useful to determine the number of factors to retain.

**Table 6: Factor Matrix (Factor Analysis at Dhawaleswaram)**

| Parameters | Factors | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| EC_FLD | **0.959** | -0.141 | -0.049 |
| pH_FLD | 0.544 | -0.164 | 0.069 |
| TDS (mg/L) | 0.921 | -0.187 | 0.222 |
| Cl (mg/L) | 0.725 | -0.147 | 0.286 |
| HAR_Ca (mg $CaCO_3$/L) | 0.909 | -0.405 | -0.047 |
| HAR_Tot (mg $CaCO_3$/L) | 0.865 | -0.253 | -0.414 |
| Na% (%) | 0.700 | 0.645 | -0.213 |
| RSC | 0.456 | 0.477 | 0.608 |
| SAR | 0.540 | 0.779 | -0.242 |

From the above cited table 6, EC_FLD has the higher absolute value of the loading. The higher the absolute value of the loading, the more the factor contributes to the variable. In Factor Analysis for Rajahmundry station was attempted to extract 3 factors. In iteration 25, the communality of a variable exceeded 1.0. Extraction was terminated. Hence, Factor Matrix was also terminated.

The table 7 cited below, shows the percent of variance attributable to each factor and the cumulative variance of the factor and the previous factors. The below mentioned table gives the highest percentage variance, obtained among the extracted values.

**Table 7: Total Variance (PCA at Rajahmundry)**

| Factor | Initial Eigen values | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % variance | Cumulative % | Total | % variance | Cumulative % | Total | % variance | Cumulative % |
| 1 | 3.570 | 39.670 | 39.670 | 3.570 | 39.670 | 39.670 | 3.434 | 38.156 | 38.156 |
| 2 | 2.728 | 30.307 | 69.976 | 2.728 | 30.307 | 69.976 | 2.427 | 26.969 | 65.125 |
| 3 | 1.037 | 11.527 | 81.503 | 1.037 | 11.527 | 81.503 | 1.474 | 16.378 | 81.503 |

**Table 8: Total Variance (PCA at Dhawaleswaram)**

| Factor | Initial Eigen Values | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % variance | Cumulative % | Total | % variance | Cumulative % | Total | % variance | Cumulative % |
| 1 | 5.276 | 58.626 | 58.626 | 5.276 | 58.626 | 58.626 | 4.464 | 49.604 | 49.604 |
| 2 | 1.667 | 18.525 | 77.151 | 1.667 | 18.525 | 77.151 | 2.479 | 27.547 | 77.151 |

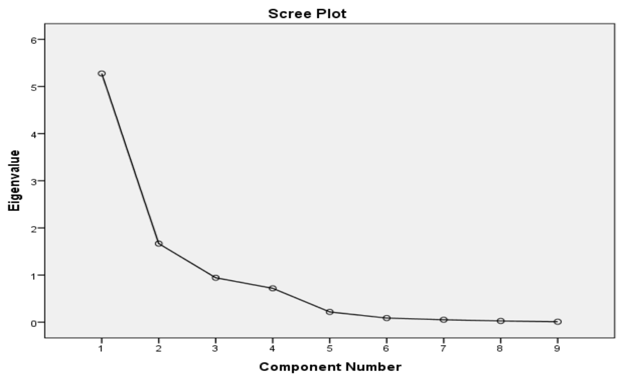



Figure 3: Scree Plot (PCA at Dhawaleswaram)


Figure 4: Scree Plot (PCA at Rajahmundry)

**Table 9: Component Matrix (Principal Component Analysis at Rajahmundry and Dhawaleswaram)**

| Study Area | Rajahmundry | | | Dhawaleswaram | |
|---|---|---|---|---|---|
| Parameters | Components | | | Components | |
| | 1 | 2 | 3 | 1 | 2 |
| EC_FLD | **0.902** | **0.338** | **0.118** | **0.957** | -0.130 |
| pH_FLD | -0.104 | 0.558 | 0.744 | 0.616 | -0.249 |
| TDS (mg/L) | 0.936 | 0.275 | 0.067 | 0.924 | -0.175 |
| Cl (mg/L) | 0.745 | 0.276 | -0.172 | 0.771 | -0.160 |
| HAR_Ca (mg/l) | 0.194 | 0.720 | - | 0.901 | -0.387 |
| HAR_Tot (mg /l) | 0.790 | 0.173 | -0.227 | 0.855 | -0.246 |
| Na% (%) | 0.431 | -0.842 | -0.130 | 0.695 | 0.648 |
| RSC | 0.313 | -0.632 | 0.586 | 0.472 | 0.536 |
| SAR | 0.607 | -0.702 | 0.154 | 0.533 | 0.784 |

From the above cited table 9, EC_FLD has the higher absolute value of the loading. The higher the absolute value of the loading, the more the component contributes to the variable.

In the Cluster Analysis, the first outcome of the analysis is proximity matrix. The proximity matrix table shows the squared Euclidean distance of each pair of cases. The values on the diagonal are 0, since a case does not differ from itself. The agglomeration schedule table shows the change in the distance measure is as additional cases are merged into clusters. The column labeled coefficients has the values of the distance statistic used to form the cluster; and a good cluster

sees a sudden jump in the distance coefficient. The solution before the gap indicates the good solution. The dendogram plot shows, how far (or close) cases were, when they were combined. The length of the branch (or link) shows how far apart each case is from the other cases, in its cluster. The plot rows represent each case on the y-axis and the x-axis is a rescaled distance coefficients. Cases with low distance/ high similarity are close together.

**Table 10: Agglomeration Schedule (Cluster Analysis at Rajahmundry)**

| Stage | Cluster Combined | | Coefficients | Stage Cluster First Appears | | Next Stage |
|---|---|---|---|---|---|---|
| | Cluster 1 | Cluster 2 | | Cluster 1 | Cluster 2 | |
| 1 | 8 | 9 | 1.44 | 0 | 0 | 3 |
| 2 | 4 | 7 | 327.44 | 0 | 0 | 4 |
| 3 | 2 | 8 | 798.76 | 0 | 1 | 6 |
| 4 | 4 | 5 | 3612.10 | 2 | 0 | 6 |
| 5 | 3 | 6 | 6512.10 | 0 | 0 | 7 |
| 6 | 2 | 4 | 19519.66 | 3 | 4 | 7 |
| 7 | 2 | 3 | 106343.92 | 6 | 5 | 8 |
| 8 | 1 | 2 | 372724.91 | 0 | 7 | 0 |

The agglomeration schedule table 10 shows the formation of clusters as change in the distance, is the measure as additional cases are merged into clusters. The column labeled coefficients has the values of the distance statistic, used to form the cluster; and a good cluster sees a sudden jump in the distance coefficient. The solution before the gap indicates the good solution. For example, we can see that there is a large jump between cases 5 and 6, corresponding to combining cluster 1(cases 8, 9, 2) and cluster 2 (cases 4, 7, 5), cluster 3(cases 3 and 6) and cluster 4(cases 1 and 2). Another possible cluster solution is a two- cluster solution, because of the large jump between stages 7 and 8, forming cluster 1 (cases 8, 9, 2, 4, 7, 5) and cluster 2 (cases 8, 9, 2, 4, 7, 5, 3, 6). The agglomeration schedule shows that, cases 8 and 9 are combined in a cluster first at stage 1(the cluster is labeled 8 since the cluster number is always the lowest of the case numbers in the cluster). At stage 2, cases 4 and 7 form to become cluster 2. At stage 3, cases 2 and 8 to form cluster 1(cases 8, 9, and 2). At stage 4, the case 4 is combined with case 5 to form cluster 2. At stage 5, the case 3 is combined with case 6 to form cluster 3. At stage 6 and 7, case 2 combined with cases 4 and 3 to form a cluster. At stage 8, case 1 is combined with 2 to form the final cluster.

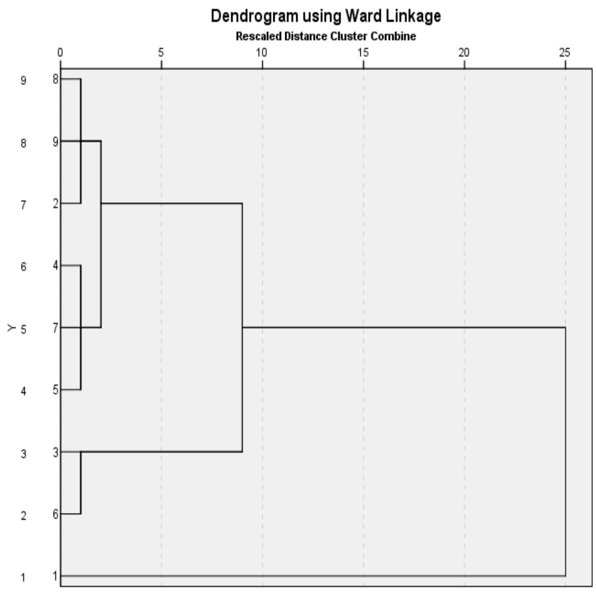



**Figure 5: Dendogram Using Ward Linkage (Cluster Analysis at Rajahmundry)**

**Table 11: Agglomeration Schedule (Cluster Analysis at Dhawaleswaram)**

| Stage | Cluster Combined | | Coefficients | Stage cluster First Appears | | Next Stage |
|---|---|---|---|---|---|---|
| | Cluster 1 | Cluster 2 | | Cluster 1 | Cluster 2 | |
| 1 | 8 | 9 | 4.00 | 0 | 0 | 3 |
| 2 | 6 | 7 | 318.50 | 0 | 0 | 4 |
| 3 | 2 | 8 | 789.16 | 0 | 1 | 6 |
| 4 | 4 | 6 | 4030.00 | 0 | 2 | 6 |
| 5 | 3 | 5 | 9339.00 | 0 | 0 | 7 |
| 6 | 2 | 4 | 22003.00 | 3 | 4 | 7 |
| 7 | 2 | 3 | 113662.00 | 6 | 5 | 8 |
| 8 | 1 | 2 | 390746.46 | 0 | 7 | 0 |

The agglomeration schedule table 11 shows the formation of clusters, as change in the distance is the measure, as additional cases are merged into clusters. The column labeled coefficients has the values of the distance statistic used to form the cluster; and a good cluster sees a sudden jump in the distance coefficient. The solution before the gap indicates the good solution. For example, we can see that there is a large jump between cases 5 and 6, corresponding to combining cluster 1(cases 8, 9, 2) and cluster 2 (cases 6, 7, 4) and cluster 3(cases 3 and 5) and cluster 4(cases 1 and 2). Another possible cluster solution is a two- cluster solution because of the large jump between stages 7 and 8, forming cluster 1 (cases 8, 9, 2, 6, 7, 4) and cluster 2 (cases 8, 9, 2, 6, 7, 4, 3, 5). The agglomeration schedule shows that cases 8 and 9 are combined in a cluster first at stage 1(the cluster is labeled 8 since the cluster number is always the lowest of the case numbers in the cluster). At stage 2, cases 6 and 7 form to become cluster 2. At stage 3, cases 2 and 8 to form cluster 1(cases 8, 9, and 2). At stage 4, the case 4 is combined with case 6 to form cluster 2. At stage 5, the case 3 is combined with case 5 to form cluster 3. At stage 6 and 7, case 2 combined with cases 4 and 3 to form a cluster. At stage 8, case 1 is combined with 2 to form the final cluster.

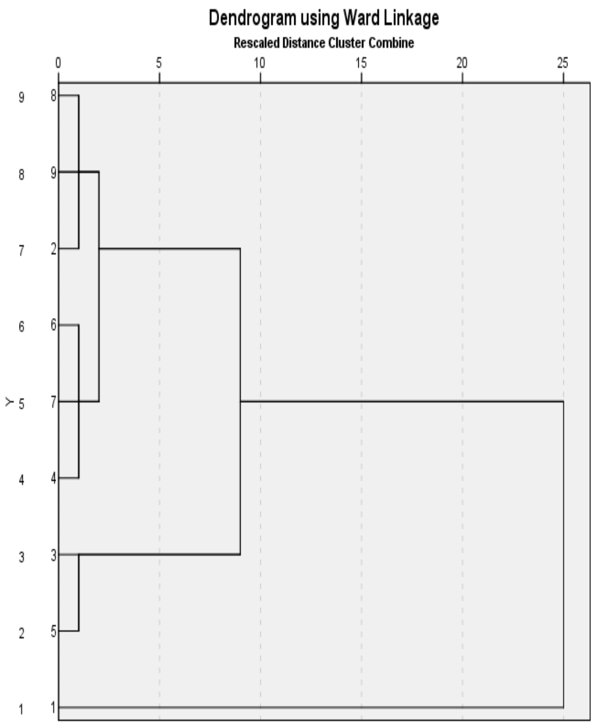



**Figure 6: Dendogram Using Ward Linkage (Cluster Analysis at Dhawaleswaram)**

## CONCLUSIONS

- The WQI computed for River Godavari at both Rajahmundry and Dhawaleswaram, is found to be fair in NSFWQI and WAIWQI method and is suitable for irrigation purposes.
- From the Factor Analysis (FA) conducted at both Rajahmundry and Dhawaleswaram, it can be concluded that EC_FLD has the greater influences on the quality of water, with 57.21% of variance.
- The Cluster Analysis (CA) conducted at both Rajahmundry and Dhawaleswaram show that, EC_FLD and TDS affects the degrees of pollution at both Rajahmundry and Dhawaleswaram.
- Based on the results obtained from Principal Component Analysis (PCA), it can be concluded that EC_FLD has the greater influences on the quality of water with 58.62% of variance.
- From the above cited statistical analysis it can be concluded that, the total dissolved solids which include SAR and RSC affect the degree of pollution at both Rajahmundry and Dhawaleswaram considerably.

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